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THESIS

A HYPERTEXT-BASED COMPUTER ARCHITECTURE
FOR MANAGEMENT OF THE JOINT COMMAND,
CONTROL AND COMMUNICATIONS CURRICULUM

by

James M. Child

June, 1992

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Co-Advisor: Dan C. Boger

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The objective of this thesis is to develop a computer based architecture for curriculum management of the Command, Control and Communications (C^3) curriculum. The architecture is based on hypertext technology. Knowledge elements are defined for Educational Skill Requirements (ESRs) and core courses, and they are used as key components in the architecture. A general assignment model, that uses knowledge elements, has been included as an aid in curriculum management. The feasibility of implementing the proposed architecture is also discussed. Seven appendices have been included which contain lists of knowledge elements, core courses, a course matrix, Educational Skill Requirements and a discussion of hypertext and multmedia. The software product the author produced using hypertext technology, which is the first implementation of the architecture described in this thesis, can be obtained from the C^3 curricular Office.

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CONTROL AND COMMUNICATIONS CURRICULUM

by

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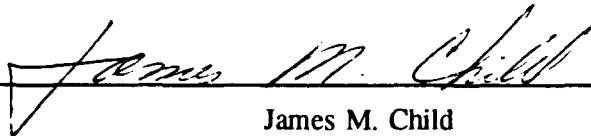of the requirements for the degree of

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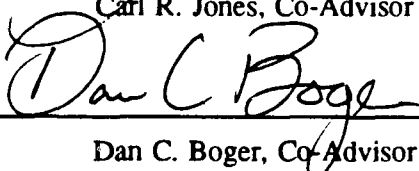from the

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ABSTRACT

The objective of this thesis is to develop a computer-based architecture for curriculum management of the Command Control and Communications (C^3) curriculum. The architecture is represented using hypertext technology. Knowledge elements are defined for Educational Skill Requirements (ESRs) and core courses, and they are used as key components in the architecture. A general assignment model, that uses knowledge elements, has been included as an aid in curriculum management. The feasibility of implementing the proposed architecture is also discussed. Seven appendices have been included which contain lists of knowledge elements, core courses, a course matrix, Educational Skill Requirements and a discussion of hypertext and multimedia. The software product the author produced using hypertext technology, which is the first implementation of the architecture described in this thesis, can be obtained from the C^3 curricular Office.

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I. INTRODUCTION

A. SCOPE

"Welcome to the Naval Postgraduate School; here is your floppy disk." These words could be used in the very near future to greet students entering the Naval Postgraduate School (NPS). The floppy disk would contain a digitized greeting from the Superintendent, several maps of the campus, photographs of key personnel, introductions to the different curricula, and many other items that would help a new student get acquainted with the school and the faculty. New students could use these disks throughout their stay here at NPS.

This scenario is not an idea that might occur in 5 to 10 years. The technology that makes it possible is here today. This thesis will produce a hypertext-based computer architecture for the Joint Command, Control and Communications (C^3) curriculum using the technology that makes the opening scenario a reality.

B. ORGANIZATION

This thesis is organized into three areas, namely: analysis and design, using hypertext, and the architecture. There are several appendices that give the reader

greater detail on subjects within the thesis. The thesis ends with some conclusions

and recommendations.

II. C³ CURRICULUM ANALYSIS AND DESIGN

This thesis will examine the Command Control and Communications Curriculum (C³) core courses along with the C³ curriculum Educational Skill Requirements (ESRs). The ESRs are the requirements that constitute the curriculum objectives. The author has not modified the objectives or the ESRs in any way. The analysis of the core courses was done on the current list of courses a C³ student must pass or validate to complete his or her graduate education. No attempt was made to examine elective courses. The list of possible elective courses can be very long and can be from any department at NPS. Finally, the ESRs and core courses were decomposed into knowledge elements and are discussed in the sections below.

A.   KNOWLEDGE ELEMENTS

What are knowledge elements and where did they come from? Professors Carl Jones and Dan Boger met with the author at the beginning of work on this thesis to define what they could call the information components that are obtained when an ESR or core course is decomposed. It was apparent that the same information was used in both ESRs and core courses but in different ways. The difference between the two areas was the manner in which the information was

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grouped. In ESRs the information was grouped by a particular ESR and could cover several courses. In the core course area the information was grouped by material normally taught in one course. After several variations it was decided that "knowledge elements" was the best description for the first level decomposition of ESRs and core courses.

Some knowledge elements have other knowledge elements as a prerequisite. This can be understood by an examination of math courses. A student can't proceed to a more advanced topic without first learning the basics. This thesis does not list any prerequisites for knowledge elements. It merely acknowledges that these prerequisites exist and should be taken into account when working with the details of knowledge elements.

Core courses and Educational Skill Requirements (ESRs) can be decomposed into knowledge elements. A better understanding of ESRs and core courses can be achieved by doing this. It also allows for a better matching of courses and ESRs. This will be examined in more detail later in this thesis.

B.   DECOMPOSING C^3 ESRs INTO KNOWLEDGE ELEMENTS

Decomposing ESRs into knowledge elements is the first step the author took in the curriculum analysis. The author started with the complete list of curriculum objectives and ESRs. Then he reviewed the list of ESRs and stated the courses that are required to fulfill that particular ESR. In some cases only a small part of

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a course is required to satisfy part of a particular ESR. The author then created the knowledge elements needed to satisfy each ESR. Again, this was accomplished by looking at what the ESRs required and what the different courses had in them.

Finally, the author had a working list of ESRs and the associated knowledge elements. This list was reviewed several times by Professor Jones, Professor Boger, and the author. The reviews helped ensure all ESRs were completely satisfied and that every course contributed to at least one ESR.

A complete list of the C^3 ESRs, and the knowledge elements that compose each ESR, can be found in Appendix A.

C. ALLOCATING KNOWLEDGE ELEMENTS TO CURRICULUM AREAS

Curriculum areas are a collection of courses with a single theme. Such areas are a natural part of any curriculum. The C^3 curriculum is composed of several curriculum areas. These areas include C^3, communication engineering, information systems, and operations analysis.

Communication engineering is an example of a curriculum area. It is comprised of the following courses:

- MA 1117 - Single Variable Calculus
- MA 1248 - Applied Mathematics

- EO 2710 - Introduction to Signals

- EO 2750 - Communications Systems

- EO 3750 - Communications Systems Analysis

A student must take or validate all the courses in this area to fulfill the curriculum graduation requirements.

Knowledge elements were assigned to curriculum areas using the decomposed ESRs discussed in section B above. This was a necessary step in obtaining the list of knowledge elements assigned to individual courses discussed in section D below.

D. ALLOCATING KNOWLEDGE ELEMENTS TO COURSES

Assigning knowledge elements to core courses was easy once knowledge elements for the curriculum areas were identified. Curriculum areas reduce the number of knowledge elements that must be examined. The author compiled a complete list of all core courses and obtained a course matrix for the curriculum. The list of core courses and course matrix can be found in Appendix B. A draft list of knowledge elements for each course was prepared and reviewed. After several revisions a final draft list was prepared.

After the final draft list of the decomposed core courses was completed, the author talked to the professors that are responsible for each core course (sometimes referred to as the course coordinator). Appendix C has a complete list of the dates

and professors the author talked to about each course. The author reviewed the knowledge elements for each course with each professor. The professors made the corrections they felt were needed after the author explained what his thesis was about, what assistance he needed from them, what knowledge elements were, and how they related to their course. The author revised his list of knowledge elements by core course when the visits with the professors were completed. The author then took the revised list and reviewed it with the C^3 Group Chairman, Prof. Carl Jones, and the C^3 Academic Associate, Prof. Dan Boger. They decided to end the review-revise-review process at this point. They agreed with the revisions the course coordinators had made. The review-revise-review process should continue until all parties agree with the knowledge elements listed for each course when revisions are made in the future.

Appendix D contains the completed list of knowledge elements listed by core course.

E. MAPPING COURSE AND ESR KNOWLEDGE ELEMENTS

It is important to understand how the core courses and ESRs map to each other. Students often ask why they have to take a certain course. Many times the answer is that "it is part of the curriculum." Although this is a true statement, a better explanation is warranted. The mapping of core courses and knowledge elements gives students a better understanding of why they are taking a particular

course and how it fits in with the overall curriculum objectives. Students can readily observe the breakdown of curriculum objectives into ESRs and also what knowledge elements make up each course. All of this information will help educate the students in the curriculum as to why the curriculum is organized the way it is. The mapping of core courses and ESRs to each other is proving to be a valuable tool in the management of the curriculum. This will be discussed in more detail later in the thesis.

Appendix E contains a list of ESRs mapped to courses. Appendix F contains a list of courses mapped to ESRs. The two lists, while containing much the same information, are necessary in ensuring that all knowledge elements map to at least one course and that each course has at least one knowledge element mapped to it. For example, the author discovered that during the process of compiling and mapping knowledge elements, one course on the final draft list was not mapped to any knowledge elements. This error was corrected once it was identified. This process error is just one small but important example of how these two lists can be used and why they are important.

Knowledge elements change when the ESRs change. The knowledge elements, while they remain the nucleus of this architecture, must change when the curriculum sponsor, who views the ESRs as the nucleus of the curriculum, changes the ESRs. These changes often take place during or just following a curriculum

review and are meant to change the curriculum so that it more accurately teaches skills and knowledge to C^3 students that the sponsor wants them to have.

F. SKILLS TO BE ACQUIRED FROM KNOWLEDGE ELEMENTS AND COURSES

What skills were acquired from the completed course? These skills are the direct result of instructors teaching students the knowledge elements. These skills should be germane to the courses where they are included. An example of a skill acquired from a knowledge element is the ability to determine the area under a curve. This skill requires the student to be able to integrate the function describing the curve, along with other more general math skills.

Did the knowledge elements lead the student to the skills acquired from the completed course? This question helps ensure that what is being learned in different courses is what should have been taught by the instructors. If students are learning how to identify different type of rocks instead of the history of command and control then maybe a review is required of what makes up the course and what the course instructor is teaching.

The mapping of skills and knowledge elements has not been completed, but has been left for further research, review, and examination by other student(s) and faculty. The author made no attempt at collecting these skills. He does

acknowledge that they exist and should be analyzed and mapped to knowledge elements and core courses.

G.   APPLYING SKILLS TO REAL WORLD EXAMPLES

A student must be able to apply the skills they have acquired to real world examples. Many professors are able to incorporate these examples into the courses that they teach. These skills are what the students will use when they go out and start using the knowledge that they should have gained from the curriculum.

The mapping of applications, skills and knowledge elements to each other is not addressed in this thesis. It is an area that should be examined to ensure that there is a consistent flow from the list of knowledge elements to acquired skills and finally to the application of those skills to real world examples.

III. HYPERTEXT USES IN THE C³ CURRICULUM

Hypertext is a method of accessing data using non-linear procedures. An expanded discussion of hypertext and multimedia can be found in Appendix G. Hypertext is gaining in popularity. The MicroSoft Windows[1] environment uses hypertext for its help functions. Other Windows products, such as WordPerfect for Windows, Excel, and Mathcad, also use hypertext for their help functions. Hypertext is also used widely on Macintosh[2] computers for many similar functions. Hypertext can be employed by many different areas. One of the first areas to use hypertext is the educational community. The Defense Language Institute (DLI) located in Monterey California is using Hypertext to teach the Russian language.[Ref 1] Stanford University is using hypertext to help medical students learn surgical skills.[Ref 2] These are just a few of the many examples of hypertext being put to use today.

Hypertext is not used much in the C³ curriculum today. There has been no overt effort to employ this powerful technology. The curriculum has acquired personal computer software that uses hypertext. However, this was not the intent of the software purchase but rather a pleasant by-product. It is the feeling of the

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[1]MicroSoft Windows is a Trademark of MicroSoft Corporation.

[2]Macintosh is a Registered Trademark of Apple Computer Corporation.

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author that hypertext could be used in a number of ways within the curriculum. The introduction of this technology could open new opportunities within the curriculum.

A. INTELLIGENT TUTORING WITH HYPERTEXT AND MULTIMEDIA

Wouldn't it be nice if a student could sit down at a computer and get some individualized, one-on-one instruction on a particularly difficult subject? Many students, including the author, find themselves desiring more instruction on a particular subject but don't have access to the instructor at that time. An intelligent tutoring system that uses hypertext and multimedia could be the answer to such a problem. Intelligent tutoring systems can be thought of as an intelligent computer aided instruction (CAI) system. Unlike traditional CAI, an intelligent tutoring system tailors its instruction for each student. These instructional modifications are based upon responses given by the student while using the intelligent tutoring system. Thus, when a student shows a lack of knowledge, by virtue of his or her answers, the system spends more time instructing in that area. Obviously, this type of non-linear approach to learning fits in very well with hypertext. The learning process is greatly enhanced by the benefits different media types offer when they are included. These are discussed below.

There are many different media types that can be included in an intelligent tutoring system. These media types include, but are not limited to, video cassette

recorders (VCRs), digitized sound, digitized video and CD disks. These media types can all be used in conjunction with the text and graphics that are used on computer systems today.

One of the most important points that a system of this type should have is future expandability. As the system is implemented, its use will become more popular and will require expansion. If there is no plan for expansion then the system's ability to keep up with changes made within the curriculum will be severely limited. This includes any modifications that could or should be made to the intelligent tutoring system.

B. OTHER USES

The list of future hypertext uses in the C^3 curriculum is only limited by one's imagination. The use of hypertext can be expanded to every office and curriculum here at the Naval Postgraduate School (NPS). The list of other uses can include an on-line database containing the photographs of students, instructors and school administrators. These photographs could be accompanied by a short biographical sketch. A map of the campus could be provided that includes historical information for that particular building and the lay-out of each floor of the building, including room numbers. Students could locate the rooms that courses will be taught by accessing such a map. Copies of Superintendent's Guest Lectures (SGLs) could be made and stored for future student or school use. Instructors

could video tape lectures that they are giving and include them in an intelligent tutoring system. All of these items use hypertext to keep track of where the information is and to display it for the user. The management of the C^3 curriculum could also be aided by using hypertext. This last area will be discussed in the next chapter.

IV. MANAGING THE C³ CURRICULUM

Management of some areas in the C^3 curriculum can be aided by employing knowledge elements. Knowledge elements are the central element within the C^3 curriculum. The use of knowledge elements enables the curriculum management to perform periodic reviews of courses and ESRs. It also allows the curriculum management to match instructors and courses. The addition of required skills in support of knowledge elements and the application of those skills should also be an integral part of curriculum management.

The C^3 curriculum management used knowledge elements during the March 1992 C^3 curriculum review. These lists allowed the participants to get a better understanding of the curriculum objectives, ESRs making up each objective, the knowledge elements making up each ESR, and the knowledge elements required for each course. This material was printed out for the participants and was also given to the course coordinators. Having the ESRs and core courses decomposed was useful for the curriculum review.

A. AN ASSIGNMENT MODEL APPROACH FOR KNOWLEDGE ELEMENTS, COURSES, AND INSTRUCTORS

In order to facilitate further work in decomposing a curriculum, the author has formulated a general assignment model. The model uses different variables to help determine what courses instructors need to teach. The general assignment model, as its name implies, is for general use though. The model could be used to determine changes to ESRs, the necessity for new courses, and the knowledge elements needed for skills that students should have at the end of a course. Obviously this is not a complete list of uses for the model. There is still a lot of work to be done on the model to refine it and to make it more useful. The general assignment model does provide the curriculum with something that is useful today. Finally, the model is currently set up to run on a quarterly basis.

The model is a derivative of a network model.[Ref 3] It uses the number of instructors, knowledge elements, courses, and the links between each to determine which instructors should teach each course. This information is gathered by identifying the links between instructors and all of the knowledge elements they possess. It also uses all links between the knowledge elements and the courses of which they are a part. The model will minimize the number of these links. That is, it will determine the fewest number of links needed to satisfy the requirements

of the model. This minimization is subject to a number of different conditions. These conditions are items such as:

1. The number of hours a particular instructor is available to teach each quarter.

2. The input to each knowledge element must be balanced by at least one output.

3. The links between knowledge elements, courses and the amount of hours required for each course that quarter.

A graphical example of the items discussed above is shown in Figure 1. Figure 2 shows a mathematical representation of the model.

The following is a procedure for implementing the model. First, collect names of all the instructors. Assign all the instructors a unique letter-number combination. Figure 1 lists these as I1, I2 and I3. These letter-number combinations ensure that no two instructors are mistaken, confused, or combined with another. Next, determine the number of hours in the quarter that each instructor is available to teach. The model in Figure 1 displays these hours to the left of the instructor's letter-number combination.

Collect all of the knowledge elements for the curriculum when the above step is completed. The author has listed these knowledge elements by ESR in Appendix A and by core course in Appendix D. Take the core course list and give each

knowledge element a unique letter-number combination. Again, the model in Figure 1 lists the knowledge elements as K1, K2, K3, K4, K5, K6, K7, and K8. These letter-number combinations help keep each knowledge element separate from the other knowledge elements.

Next, decompose the instructor's knowledge into knowledge elements. This, by its very nature, is subjective. Certainly the relevant department chairman should be a very active participant in this part of the process. Now, map each instructor to the knowledge elements she or he possesses. The link between each instructor and an individual knowledge element has a value of 0 or 1. Assign a 0 if there is no link and a 1 if the link exists. Each of these links can be uniquely identified by combining the letter-number combination from an instructor and each knowledge element he or she possesses. The links shown for instructor 1 (I1) in Figure 1 and the knowledge elements he or she possesses (K1, K4 and K5) are listed as I1K1, I1K4 and I1K5. A mathematical representation of these links is shown on lines 2, 3 and 4 of Figure 2. For example, the number of hours that instructor 1 is available must be distributed between knowledge elements K1, K4 and K5. Consequently the mathematical representation, as shown in Figure 2, for instructor 1 must be constructed as follows:

$$I1K1 + K1K4 + I1K5 \leq 80$$

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Figure 1

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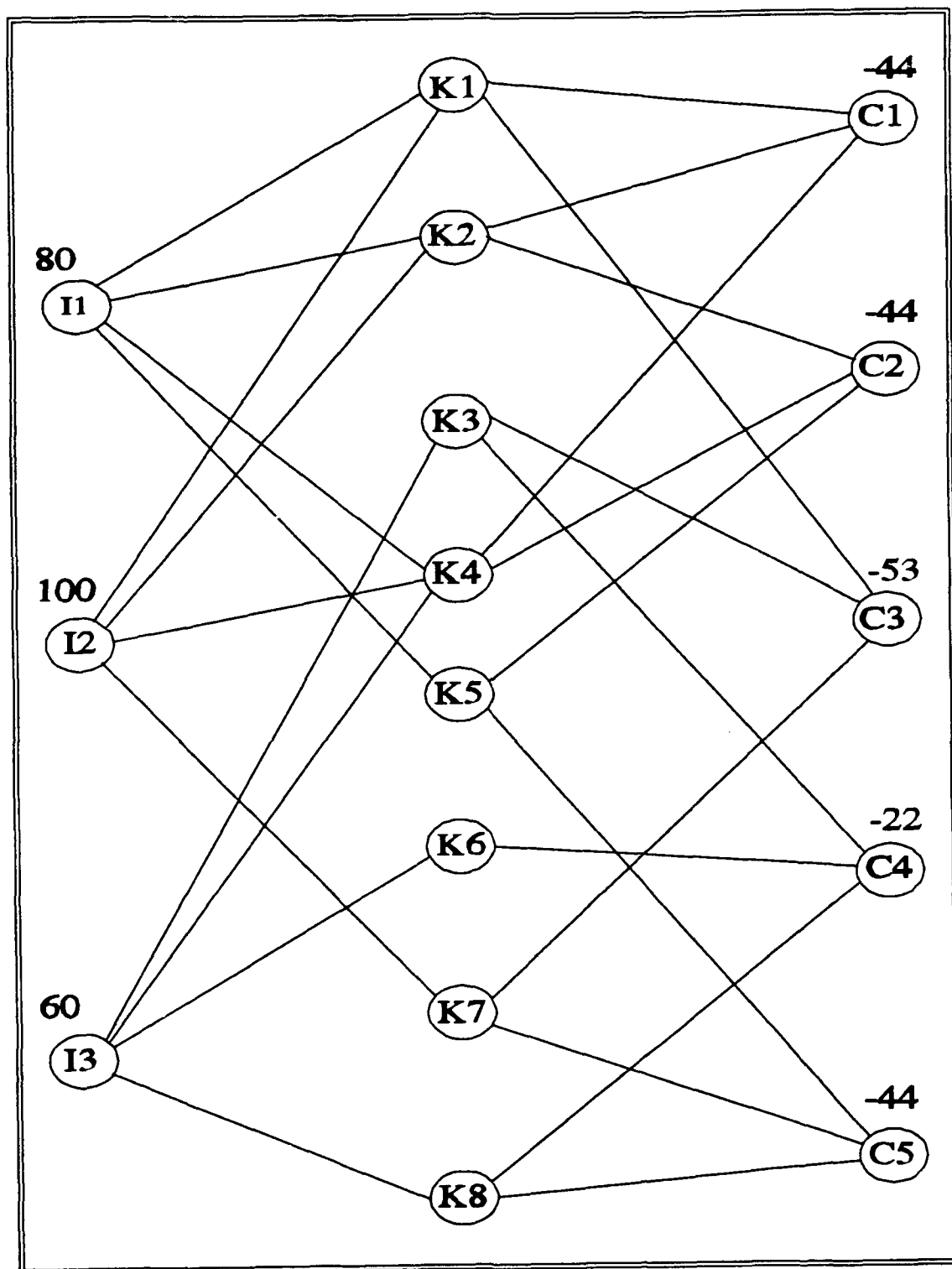
min I1K1 + I1K2 + I1K4 + I1K5 + I2K1 + K2K2 + I2K4 +

      I2K6 + I3K3 + K3K4 + I3K5 + I3K7 + K1C1 + K1C3 +

      K2C1 + K2C2 + K3C3 + K3C4 + K4C1 + K4C2 +

      K5C2 + K5C5 + K6C4 + K7C3 + K7C5 + K8C4 + K8C5

Subject To

    2) I1K1 + I1K4 + I1K5 =< 80

    3) I2K1 + I2K2 + I2K4 + I2K7 =< 100

    4) I3K3 + I3K4 + I3K6 + I3K8 =< 60
       K1C1 + K2C1 + K4C1 = 0

    5) -I1K1 - I1K2 - I1K4 - I2K1 - I2K2 - I2K4 +
       K1C1 + K2C1 + K4C1 = 0

    6) -I1K2 - I1K4 - I1K5 - I2K2 - I2K4 - I3K4 +
       K2C2 + K4C2 + K5C2 = 0

    7) -I1K1 - I2K1 - I2K7 - I3K3 + K1C3 + K3C3 +
       K7C3 = 0

    8) -I3K3 - I3K6 - K3K8 + K3C4 + K6C4 + K8C4 = 0

    9) -I1K5 - I2K7 - I3K8 + K5C5 + K7C5 + K8C5 = 0

    10) -K1C1 - K2C1 - K4C1 = -44

    11) -K2C2 - K4C2 - K5C2 >= -44

    12) -K1C3 - K3C3 - K7C3 >= -53

    13) -K3C4 - K6C4 - K8C4 >= -22

    14) -K5C5 - K7C5 - K8C5 >= -44

End

Figure 2

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The next step is to map the knowledge elements to the core courses. Appendix D contains this list for the C^3 curriculum core courses. The value of each link between knowledge element and core course is the number of hours required to teach that particular knowledge element.

Now determine how many hours each course requires for that particular quarter. When this number is entered into the model it will be a negative number. In the graphical example shown in Figure 1 the number is to the left of or just above each course. The mathematical representation, shown in Figure 2, is constructed by subtracting the number of links from knowledge elements to courses. The mathematical representation for course 1 is represented by the equation listed on line 10 of Figure 2. If the number is listed as a positive number the model will not work. A positive number is required because knowledge elements are the only inputs to courses and courses have no outputs. The -44 associated with course C1 indicates that 44 hours of input from knowledge elements K1, K2 and K4 is required.

Finally, use a linear programming language to program the model and run it on a computer. Ensure that the model requires that each knowledge element must be taught if the course is taught. Figure 2 is an example of this model using the Lindo linear programming language.

The model, as it is currently defined, does not take into account the fact that some knowledge elements have other knowledge elements as prerequisites. Simply stated, one would have to complete knowledge element #1 before he or she could go onto knowledge element #2. The fact that knowledge element #1 was a prerequisite of #2 is coincidental. It could be that knowledge element #2 is a prerequisite of #1. Another possibility is that of concurrent knowledge elements. That is, two or more knowledge elements must be learned at the same time (e.g., #1, #2, and #3).

Currently the model uses a 0 or 1 value for the link between instructors and knowledge elements. This could be changed to be some number on a sliding scale (e.g., .1, .5, 1, 2.5). This might more accurately reflect the knowledge and abilities of each professor. Again, the department chairman should be involved in this process.

Another variation on the model might be made by allowing varying amounts of time for a knowledge element when it is linked to more than a single course. That is, knowledge element #5 might require 10 hours for course #3 and only 5 hours for course #8. The reason for this is course #3 might cover that particular knowledge element in more detail than course #8. These variations could be different for each course in the curriculum.

A new model could be defined using the original model as it is defined above but with some or even all of the variation list above included. The model can be described in the same manner as above but would have to add a numeric value to each of the links. This could be expressed as 2*I1K1, 3*I1K4 or 10*I1K5 for the instructor-knowledge element links. The value for each knowledge element-course link must be added in the same fashion. An area of the model could also include information about prerequisite knowledge elements and concurrent knowledge elements. These changes will help refine the model and allow others to work with it to improve its ability to aid the management of the curriculum.

B. COURSE MANAGEMENT

Being able to monitor what is being taught in C^3 courses is now possible on a real-time basis. For example, the author was having a discussion with some C^3 students who were about a year away from graduation. It became apparent to the author that what the students were being taught in one particular course did not correspond with the knowledge elements. The author asked the students a second time what they were learning in a course and whether it contained some of the missing knowledge elements. The students again confirmed that what they were being taught was not what the knowledge elements said should be taught. The author then talked to the C^3 Group Chairman, Prof. Carl Jones, and the Academic Associate, Prof. Dan Boger, and let them know of the discrepancies that existed

between what was being taught and what the knowledge elements stated. Prof. Jones and Prof. Boger confirmed, with the instructor, what was being taught and were able to direct a change in the course content within a few days. The course, which had been going off in the wrong direction, has been successfully brought back into alignment with the knowledge elements. This all came about because the author knew what the knowledge elements were and what the course should contain.

All students can have a clearer and more precise understanding of what a course is about and what key concepts will be covered. This can come about by making available to the students the lists of curriculum objectives, ESRs, knowledge elements listed by ESR and knowledge elements listed by core course. This information will help the student to see where he or she is at any one time while they are in the curriculum. It helps the student to be able to answer questions like "why do I have to take this course" and "what does this have to do with C^3." It also gives the students, instructors, and curriculum management a better understanding of the ESRs for this curriculum.

C. ESRs

The implications of changing ESRs is more easily understood using knowledge elements because the makeup of each ESR and what courses must be taken to meet the specified requirement(s) is known. Knowing each ESR and what

knowledge elements are required for them is important. Knowledge elements makeup ESRs. The impact that any changes to ESRs will have on the curriculum can be seen more readily. There will be no debate as to what courses are affected. The implications of changing ESRs can become a more organized and deliberate process. It can add much more focus to changes of ESRs and should help to improve the quality of the curriculum and its graduates.

Students will be able to understand why they must take certain courses. This is brought about by an increased awareness of what the ESRs are and how they are made up. The realization that knowledge elements make up courses can lead to more informed students and should help improve the consistency of material being taught by the different instructors in the curriculum.

Modifying the curriculum objectives can be done in a more organized manner by using the knowledge elements that make up each ESR. Modifying the curriculum becomes easier once an understanding of the links between knowledge elements, ESRs and curriculum objectives has been gained. Questions about whether a course will be affected by a change in the curriculum objectives or ESRS can be quickly answered. All of this understanding comes about because of the decomposition of the ESRs and courses into knowledge elements.

D. MATCHING INSTRUCTORS TO COURSES

A better matching of instructors to courses could be obtained if the department/group were to collect a list of knowledge elements for each instructor and use them in assigning courses to be taught. This has not be accomplished by the author. However, the value of such a list is recognized. The curriculum could use the list when course instructors have to be changed. The list could also be used when the curriculum is changed and a new course has to be offered or an existing course has to be expanded. Lastly, it will help the curriculum better use the abilities of each instructor.

The general assignment model can be used as an aid in this process. The list should be fairly straightforward when it is completed. It will, however, require the mutual cooperation of the C^3 Group chairman and the instructors. The general assignment model can not be used, as it has been defined above, until this list of knowledge elements is complete.

E. CURRICULUM QUALITY CONTROL

The curriculum management now has a powerful new tool at their disposal to help improve curriculum quality control efforts. The quality of the curriculum can be improved by being able to concentrate more fully on the areas that need the most improvement. These areas are more easily exposed with the use of knowledge elements. These areas can be exposed by looking at individual courses,

curriculum areas, or ESRs. The quality of instruction is increased when all courses are teaching the required knowledge elements. This means that students will have all of the skills that are required of them when they enter follow-on C^3 curriculum courses and will be better able to use the skills acquired after they have graduated.

F.   SUMMARY

Being able to link curriculum information together in a non-linear manner opens the door to many new (some of which are still undetermined) functions. Some of these functions have been discussed above. Others are still waiting to be uncovered. The author realizes that the list of new functions will, and should, grow each year. The work accomplished here has only set in motion the wheels of change. By managing the change that will certainly happen, it is hoped that a better C^3 curriculum will emerge and that the quality of students will improve.

V. THE ARCHITECTURE

What does the architecture look like and what will it do for the curriculum? This chapter will outline the architecture, discuss how to implement the architecture, describe the software to be used in the implementation and address some of the issues associated with the feasibility of the architecture

A. ARCHITECTURE OUTLINE

The architecture has three main elements: ESRs, knowledge elements, and core courses. ESRs are the first part of the architecture that are encountered. This is true for the prospective student and instructor alike. ESRs are used by the sponsor to help shape the curriculum. ESRs are broken down into knowledge elements. These are the nucleus of the architecture. The second part of the architecture allows the curriculum management to use knowledge elements to help manage the curriculum. The last part of the architecture is the list of core courses that a student must complete or validate in order to graduate.

Also included in the architecture is the influence of the curriculum sponsor, J6 of the Joint Staff. This influence is on the ESRs. When ESRs change then knowledge elements change, as discussed in Chapter IV. The sponsor's influence

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can not be left out of the architecture. The curriculum interface, defined in Figure 3, shows how the sponsor influences the curriculum through the use of ESRs.

Figure 3 also shows the relationship between knowledge elements, core courses, ESRs, and the curriculum sponsor. A thorough understanding of these relationships can help the student and instructor both understand some of the reasons the curriculum is structured the way it is and how change is effected in it by the sponsor.

1. ESRs

This area lists all ESRs and the mapping to knowledge elements that are required to satisfy the curriculum objectives. ESRs are a decomposition of the curriculum objectives. They help define what is required of C^3 students in order to reach or meet the curriculum objectives. The mapping was done to understand and ensure that all curriculum ESRs mapped to at least one knowledge element.

The mapping in this area should be reviewed periodically to ensure that it is current and accurate. This could be done on an annual, semi-annual, quarterly or biennial (during the curriculum review) basis. It can be used by the instructors, curriculum management and the sponsor to monitor and change the objectives and ESRs.
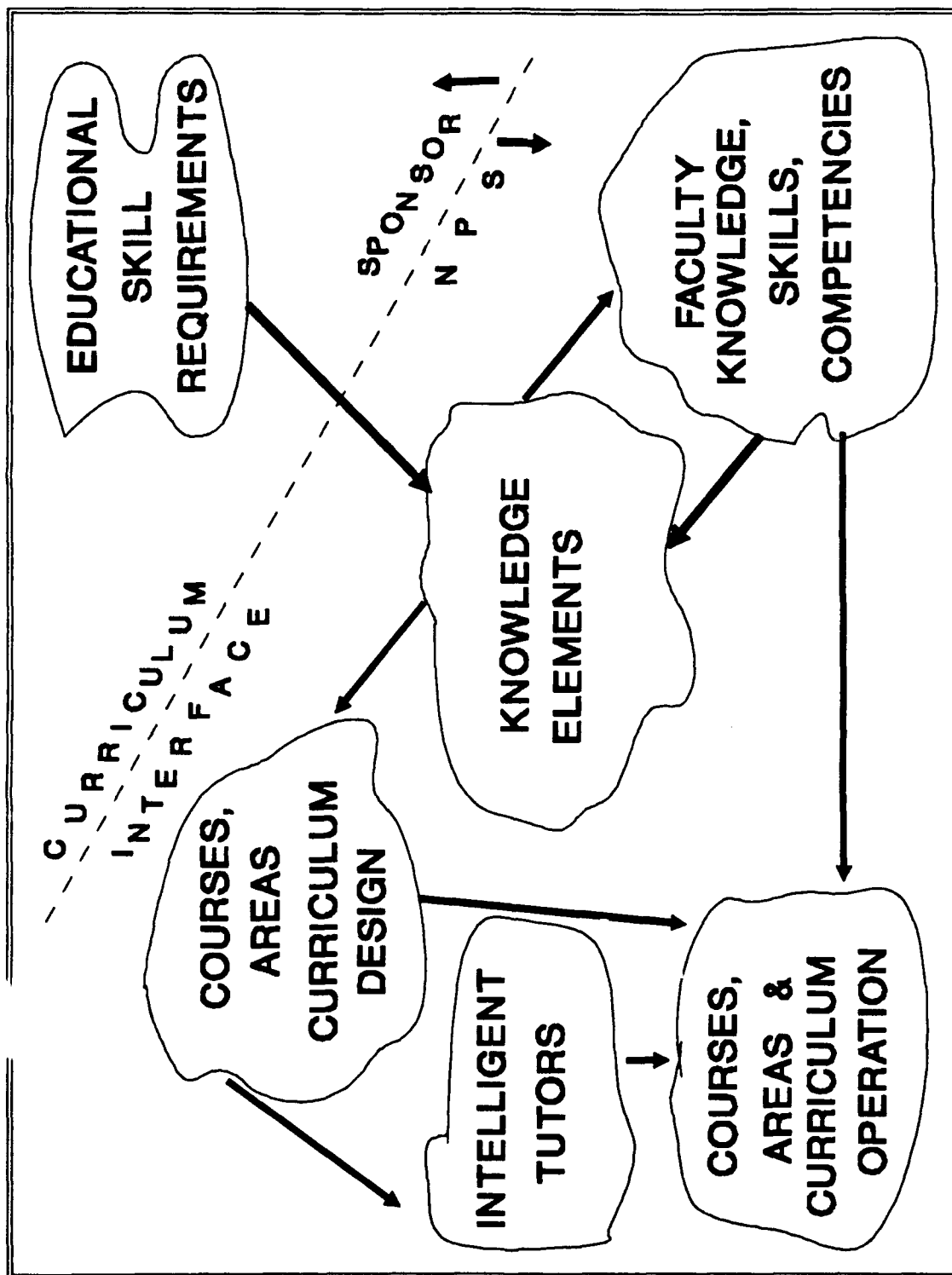
Figure 3

2. Knowledge Elements

Knowledge elements are the nucleus of the architecture. They are the essential ingredient that holds this architecture together. A more detailed discussion on knowledge elements can be found in Chapter II. Figure 3 accurately shows knowledge elements at the center of the architecture. The number of uses for knowledge elements is certainly not limited to what has been presented in this thesis. Appendix A contains knowledge elements listed by ESR. Appendix E contains the list of knowledge elements by core courses. Both of these lists should be used extensively in the implementation of this architecture.

3. Core Courses

Core courses and their mapping to knowledge elements are listed in this area (see Appendix E). Knowing what knowledge elements link to what courses helps ensure that the correct information is taught by the different instructors. This mapping also helps the instructors to take a critical look at what they are teaching in each course and make any needed adjustments. These adjustments are easier to make with a list of the curriculum objectives, ESRs and knowledge elements listed by ESR.

4. Linking Knowledge Elements, ESRs and Courses

How knowledge elements, ESRs and core courses are related to each other is the central theme of the architecture. How does one course affect another?

How does a change in an ESR affect a particular course that is being taught? What instructors does the C^3 group have that can teach these courses? These and many more questions can be addressed using the relationship between knowledge elements, ESRs and core courses.

The linking of knowledge elements, ESRs and core courses should be considered dynamic. A careful studying of Figure 3 will help the reader realize that all areas of the curriculum are linked in some form to each other. This knowledge allows for a better understanding of how the curriculum is constructed. This knowledge also enables the student to grasp the importance of all the courses that are required by the sponsor.

5. Future Areas to Be Examined

There are two areas that are natural extensions to this architecture. They are: the pool of skills acquired from each knowledge element and the application of those skills. The author made no attempt to compile any parts of these two lists. Their importance has already been discussed in Chapter II.

What is the relationship between knowledge elements and skills? Any skills that are acquired from a course must include those that are mapped from each individual knowledge element. The relationship between knowledge elements and skills is important and should be the next area to be examined when expanding this architecture.

How are the application of new skills mapped to the skills themselves and to knowledge elements? The list of the application of those skills can be created once the mapping of knowledge elements to the list of acquired skills is completed. This is followed by the mapping of those skills to applications. With this completed, a mapping of skill application to knowledge elements should be completed. This will help in filling out the big picture of the architecture.

These mappings are not the only ones that can take place. Other areas can, and probably should, be added to this architecture.

B. IMPLEMENTING THE ARCHITECTURE

Implementing this architecture can best be accomplished by using hypertext software. This fact exists because of the non-linearity of the information that is being assembled. Hypertext is ideally suited for this type of information gathering. Hypertext allows links to be made between objects or files. In this architecture these links have been represented by the connection between knowledge elements, ESRs and core courses. These links, which are dynamic, can be modified as the curriculum changes. This enables those that are maintaining the software to keep abreast of the changes in the curriculum.

C. DESCRIPTION OF THE SOFTWARE PRODUCT

Good software practice states that any software product should be accompanied by good documentation. This section describes the software that has been created to accompany this thesis. A copy of this software may be obtained from the C^3 Curricula Office.

1. Guide Hypermedia Information System

The Guide[3] Hypermedia Information System softwai ? i. used to create the hypertext files described in this architecture. "Guide is an interactive software system that gives personal computer users the ability to organize, manage, and present information in a number of formats."[Ref 4] This software was chosen for the following reasons:

- It runs on the DOS personal computers located in the C^3 computer lab. This version requires the MicroSoft Windows environment in order to run.

- A version of this software is available which also runs on the Apple Macintosh computer.

- Both the DOS version and the Macintosh version look and operate the same way.

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[3]Guide is a registered Trademark of OWL International, Inc.

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- A version of the software that will run on the UNIX[4] computer operating system is in beta testing. This product will also have the same "look and feel" as the DOS and Macintosh versions.

- The software was available for the author to use.

The software is flexible enough for the work that is being done here. However, some trouble was encountered in the creation of "buttons" used to help the user navigate around the hypertext files. This was partially due to the fact that the author did not use the any specialized software, other than Guide, to create the buttons. The Guide software allows the user to create, delete and modify all of the links and files needed to implement the architecture. Only the software maintainers should be allowed to use this software.

2. Guide Reader

Guide Reader[5] is a read-only version of Guide. This feature prevents inadvertent changes to the software from taking place. This makes possible the widespread distribution of the software product without fear that unwanted changes will take place. It is a key element that makes the use of this software possible.

Most users of this architecture should use Guide Reader. It provides all of the navigation abilities that the authoring software provides. However, the user

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[4]UNIX is a Registered Trademark of AT&T.

[5]Guide Reader is a Registered Trademark of OWL International, Inc.

can't make any changes to the files they are looking at. As the name of the software implies, it is only for reading the software.

3. Data File Descriptions

How are the data files constructed and how do they interact with each other? The data is stored in a file called C3-objct.gui and the navigation buttons are stored in a file called icon.gui. A file named startup.gui is first called when the software is started. The file named startup is used only to greet the user. It does not contain any information other than the name of the school and a means to get to the files that the user needs. The file c3-objct.gui was created using a word processor and saved as ascii text. The hypertext software was started and the ascii text was read into the new file. The links and buttons were then created with comments added where possible. This will allow easy modification of the links by someone other than the author in the future. There is a file titled my-help.gui that contains general help on using the software. This file can be expanded to include more items that will be of benefit to the users.

D. FEASIBILITY

Can the architecture be implemented as it has been outlined? Up until now this thesis has just talked about the architecture and what software can be used to

in implementing it. A critical look at some of the feasibility issues must be accomplished at this time.

1. Current Hardware and Software Availability

What hardware and software does the curriculum have that can be used in the implementation of the architecture? Currently the curriculum has seven DOS personal computers in the C^3 computer lab. These machines use Intel386[6] CPUs and run at 33 Mhz. Each machine is also equipped with a numeric floating point processors and a mouse. Each machine has ample room for the hypertext software on their its drives.

2. Implementation Requirements

The architecture requires specific hardware and software in order to be useful. The software can not be purchased, loaded on to any DOS personal computer, and expected to run without any problems. The appropriate hardware and software must be purchased.

a. Hardware

An IBM PC[7] or compatible computer is required with an optional mouse recommended. The software vendor recommends that the software run on

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[6]Intel386 is a Registered Trademark of the Intel Corporation.

[7]IBM is a Registered Trademark of International Business Machines Corporation.

a personal computer that uses the Intel386 (or equivalent) or faster CPU. The hardware in the lab meets all of these requirements and recommendations. If the architecture is expanded to include multimedia then the appropriate hardware will have to be purchased.

b. Software

The computer must be running MicroSoft Windows version 3.0 or higher in order to use the Guide Hypermedia Information System or the Guide Reader software. As stated earlier, the software to be used in implementing this architecture is Guide Hypermedia Information System. Both the authoring system and an appropriate number of copies of Guide Reader must be purchased. Current pricing information can be obtained from the software vendor[8].

c. People

The author has been implementing the architecture, but a permanent solution must be found. Someone with the curriculum, either an instructor or student, must be found to maintain the software. This is not a trivial task or one that can be ignored. If the software is to be useful then it must be maintained by someone. The author suggests that a combination of instructor(s) and student(s) be used to maintain the software. It could be under the umbrella of additional

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[8]OWL International, Inc, 2800 156th Ave South East, Bellevue, Wa 98007 (206) 747-3203

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thesis work or research. If this is not possible then perhaps an individual instructor or student would be willing to take on the responsibility. The time required to maintain the software should not be very great. The author estimates that about 1-2 hours a week would be more than enough time to keep the software current.

3.   Can the Architecture be Implemented?

Given all of the constraints listed above, is it feasible for the C^3 Curriculum to implement the architecture? The answer is yes. A lot of the work has been accomplished by this author. Without any expansion of the architecture there are sufficient resources to accomplish this task. If the architecture is expanded then the resources of the curriculum should be re-examined to ensure that the workload and money to support the effort are available.

What follows is a list of hardware and software that might be acquired by the curriculum to enhance and improve the implementation of the architecture. This list includes, but is not limited to, the following:

- CD ROM disk drives

- VCR

- Voice digitizer

- Sound boards for the DOS personal computers, such as Sound Blaster or AdLib

- Video camera

- Video digitizer

- Large screen display

- Network version of the hypertext software

- Network boards and adapters for the computers

- Cable TV adapter for the personal computers. This allows the user to receive a television picture on the monitor of their personal computer.

VI. CONCLUSIONS AND RECOMMENDATIONS

The examination of the C^3 curriculum has allowed for a hypertext-based computer architecture to be created. The author outlined the steps that were taken to decompose the ESRs into knowledge elements. The decomposition of core courses into knowledge elements was also accomplished. Knowledge elements were then mapped to ESRs and core courses. The use of a hypertext system in the C^3 curriculum was examined along with ways to manage the curriculum using knowledge elements. Finally, the architecture itself was presented. The architecture included the hardware, software and the feasibility of implementing the architecture.

There is still plenty of work to be done. The author has only completed the initial steps in this effort. The general assignment model can be expanded. The use of multi-media can be included. The software provides the "hooks" for all of these areas and the basic hardware is in place.

APPENDIX A

C3 KNOWLEDGE ELEMENTS LISTED BY ESR

This appendix contains the list of knowledge elements listed by ESR. The ESRs are organized by the four curriculum objectives. Each ESR contained in a particular objective will have the objective number plus some additional numbers added to it to uniquely identify it. For example, ESR 1.1 is in the first objective. The ESR, 1.1, has two ESRs below it that are numbered 1.1.1 and 1.1.2. From this organization anyone can tell very quickly where a particular ESR fits into the curriculum objectives and ESRs.

The knowledge elements listed here are only shown at the lowest level at which they appear. For example, a knowledge element that appears in 1.1.1 is not shown in 1.1 or under objective 1. This method assures that all knowledge elements are listed under the correct ESRs and that redundant listing of knowledge elements is eliminated.

The author made no changes or modifications to any of the curriculum objectives or ESRs. The author has only listed knowledge elements under the appropriate ESRs.

1. Analyze technical requirements and perform planning studies of C3 systems.

1.1. Understand and apply basic C3 systems technology.

1.1.1 Understand and apply basic physical principles, capabilities, and limitations of telecommunications and sensors, including radars. Include analog and digital systems with emphasis on digital systems.

- Comparative Performance of Analog and Digital Modulation Types in the Presence of Noise.

- Signal to Noise Ratio and Bit Error Rate and E_b/N_o.

- Antenna Fundamentals and Characteristics.

- Radar Equations.

- Path Calculations and Link Budget.

- Microwave (Terrestrial and Satellite) Link Equations.

- Ionospheric & Tropospheric & Meteorologic Effects on Propagation.

- Sampling Theorem.

- Modulation (PAM, PCM, TDM, FDM, QPSK).

- Noise Types and Modelling

 •• Thermal, Power Spectrum, Equivalent Noise Bandwidth, Bandpass, Noise Modulation Products.

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- AM & FM System Performance in Noise.

- Communication Systems Schematic.

- Transfer Functions

- Amplitude Response

- Phase Response.

- Ideal Filter Response.

- Non-Ideal Filter Approximations.

- Signal Description and Detection.

- Time and Frequency Domain Representations of Random Signals.

- Sequences and Series

- Fourier Series

- Periodic and Special Wave Form Analysis

- Fourier Transforms

- Time and Frequency Domain Representation of Wave Forms

- Convolution and Correlation

- Single Variable Differential and Integral Calculus.

- Real and Complex Numbers.

1.1.2   Understand the atmospheric/meteorological effects on telecommunication

and sensor systems.

- Comparative Performance of Analog and Digital Modulation types in the Presence of Noise.

- Microwave (Terrestrial and Satellite) Link Equations

- Ionospheric & Troposphere & Meteorologic Effects on Propagation

- HF Propagation

- UHF Propagation

- VHF Propagation

- Microwave(Radar) Propagation

- Fourier Transforms

- Fourier Series

- Single Variable Differential and Integral Calculus

1.2   Understand the capabilities and limitations of computers including networking,

operating systems, software and hardware, and programming concepts.

- Defense Data Network (DDN)

- Software Design

- Human Factors in Systems Design

- Speech Input

- Biometric Systems and their use in the Military

- Electronic Mail

- Ada Programming Language

- Problem Solving

- Structured Programming

- Program Design

- Recuresion

- Data Structures

- Data Types

- Basic Computer Architecture

- Principles of Digital Logic Circuits

- Elements of Microprogramming

- Principles of Assembly Language

- Modeling Networks

- Flows, Routing and Queuing in Networks 1 & 2

- Basic Networking Concepts 1 & 2

1.3   Understand data base management systems with emphasis on C3 applications.

- Fundamentals of Database Management

  •• File Processing

- •• Database Processing (Relational, Hierarchical, Networked)

- •• Data Definition

- •• Data Manipulation (Standard Query Language - SQL)

- •• Data Control (Data Integrated)

- •• Data Administration

- • Artificial Intelligence/Expert Systems Basics

- •• Knowledge Representation

- •• Inferencing

- •• Neural Networks

- • Functions and Characteristics of Decision Support Systems

- •• Models of Decision Making

- •• Components of A Decision Support System

- ••• Data Management

- ••• Model Management

- ••• User Interface

- ••• Communications Subsystem

- ••• Hardware & Physical Facilities

- •• System Design (Prototyping)

- •• Group Decision Support System

1.4. Understand Defense acquisition.

1.4.1 Understand the PPBS, evolutionary acquisition, PPPI program, NDI, COTS, and the CINC PPBS input with emphasis on command and control systems.

- History of Acquisition

- The Acquisition Process (e.g., CINC PPBS)

- DAB/Program Baseline

- PPBS/Cost Estimates

  •• Statistical Estimation

- Acquisition Strategies (e.g., COTS, NDI, PPPI, Milspec, Evol.)

- Acquisition Plan

- Contracting Process & Administration

- Test & Evaluation

- Integrated Logistics Support (ILS)

- Future C3 Systems

- Combined C3 Systems

2. Understand the technical requirements for interoperability between C3 systems and the programs designed to ensure interoperability.

2.1 Understand technical interoperability parameters of command and control systems (including the path, the information traveling on the path and the processing of the information).

- Structured Analysis of System Architecture

- Systems Engineering Process

  - •• Mission Needs

  - •• Threat Specification

  - •• Requirements Analysis

  - •• Functional Analysis

  - •• Definition of Alternative Architectures

  - •• System Analysis & Trades-Offs

  - •• Concept Selection

  - •• Concept Definition

  - •• Concept of Operations

  - •• Deliverables

- Top-Level Warfare Requirements/TLSR

- Buildability (Physical Realizability)

- Cost and Operational Effectiveness Analysis (COEA)

- National Technical Means (TENCAP)

- System Effectiveness Analysis

- System Utility Functions (Multi-Attribute Decision theory)

- Functional Analysis & Design

- DoD Standards Setting Process

- Life Cycle Costs

- System & Sub-System Interfaces

- Mission Oriented Approach (MOA)

- Modular C2 Evaluation Structure (MCES)

- Experimentation

  -- Planning Experiments

  -- Designing Experiments

  -- Conducting Experiments

  -- Analysis of Experiments

  -- Reporting Results of Experiments

- Design of Experiments (ANOVA)

- Statistical Inferences

- User-Developer Relationships

- Engineering Note Book

  -- Current System Parameters

  -- Draft Analysis, Trade-offs, & Other Studies

•• Library of Resource Material

•• Team Meeting Minutes

2.2. Analyze and evaluate C3 systems for effectiveness and efficiency through modelling and simulations.

2.2.1   Design, implement and use simulation models with emphasis on C3 and interpret the results.

- Combat Theory for C^3

- Nature of Combat Models & Modeling

- MOEs for Warfare (MOEs/MOFEs)

- Analytic Combat Models

    •• Attrition Based Models (Ground and Naval)

    •• Non-Attrition Based Models

- Current Models & Analysis (e.g., JANUS, RESA, CFAW)

- Tactical Influences on C3

- Decision Aids: Construction, Application & Limitations

- Mission Oriented Approach (MOA)

- Modular C2 Evaluation Structure (MCES)

- Planning Experiments

- Designing Experiments

- Conducting Experiments

- Modeling Process

- Simulation language Types (Generic, Specific)

- Simulation Methodology

- Simulation Algorithms

- Discrete Event Simulation

- Random Number Generation

- Input Data Analysis

- Verification & Validation

- Sample Size and Replication

- War Gaming

  •• Types of War Games (e.g., Seminar, Computer Assisted)

- Specific War Games (e.g., JANUS, RESA)

- Test of Hypothesis

- Design of Experiments (ANOVA)

- Linear Regression

- Analysis of Categorical Data

2.2.2   Understand the relationships of intelligence, air operations, fire support and maneuver, maritime, administration and logistics, and management information systems to the C3 function.

- Functions of Command

- Process of Command & Control

- Combat Operations

- Maneuver Warfare

- U.S. National Command Structure

- NATO C3

- Military Strategy & National Objectives

- Strategic Nuclear Command and Control

- Individual Service Doctrine

- Tactical Command & Control

- Naval Space Master Plan (e.g., Navigation, Communication, Surveillance Systems)

- National & Defense Communications Systems (e.g., WWMCCS, DSCS)

- C3 Personnel Issues

- Historical Perspectives of C3

- Historical Evolution of Strategy, Maritime Strategy, and U.S. Defense Policy

- Principles of War

- Chain of Command

- Joint Planning Doctrine & Organization

- Service Unique Doctrine

  •• Navy

  •• Army

  •• Air Force

  •• Marine Corps

  •• Coast Guard

- Alliance and Regional Policy Issues

- Nuclear Issues

- Arms Control

- Other Navies

- Military Force and Foreign Policy

- Current Issues in Defense Reform/Reorganization

- Combined C3 Systems

- National C3 Policy

2.3 Be familiar with programs and organizations (agencies, boards and panels) associated with interoperability including the OSD/C3I, MCEB, IIP, JTC3A Center for Standards, TPC3 Panel, and the Five Year Interoperability Assurance Plan

(FYIAP); and, use the architectures developed by DISA, JTC3A (FIA's), DIA

(TIAP, INCA), as current examples.

- C3 Process & Organization

    •• OSD/C3I

    •• MCEB

- Architecture Examples

    •• FIA

    •• INCA

    •• Copernicus

- DoD/National/International Standards Setting Process

- C^3 Master Plans

3. Understand the role of C3 systems in military operations.

3.1. Understand the role of C3 systems in the use of military

power.

3.1.1   Understand C3 systems.

3.1.2   Understand the C3 management structure of DoD.

3.1.1 & 3.1.2

- Functions of Command

- Process of Command & Control

- U.S. National Command Structure

- NATO C3

- Strategic Nuclear Command and Control

- Individual Service Systems

- Tactical Command & Control

- Naval Space Master Plan (e.g., Navigation, Communication, Surveillance)

- National & Defense Communications Systems (e.g., DCCS, WWMCCS)

- C3 Personnel Issues

- Historical Perspectives of C3

- C3 in Crisis

- Joint Headquarters C3 Systems

3.1.3   Understand the structure of DoD and Joint and Unified Commands.

- Functions of Command

- Process of Command & Control

- Combat Operations

- Maneuver Warfare

- U.S. National Command Structure

- NATO C3

- Military Strategy & National Objectives

- Strategic Nuclear Command and Control

- Individual Service Doctrine

- Tactical Command & Control

- C^3 Master Plans

- National & Defense Communications Systems

- C3 Personnel Issues

- Historical Perspectives of C3

- Historical Evolution of Strategy, Maritime Strategy, and U.S. Defense Policy

- Principles of War

- Chain of Command

- Joint Planning Doctrine & Organization

- Service Unique Doctrine

  •• Navy

  •• Army

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- • Air Force

- • Marine Corps

- • Coast Guard

- Alliance and Regional Policy Issues

- Nuclear Issues

- Arms Control

- Other Navies

- Military Force and Foreign Policy

- Current Issues in Defense Reform/Reorganization

3.2. Understand the threat to C3 systems.

3.2.1   Understand the availability of intelligence products.

- National Technical Means (TENCAP)

- C3 in Crisis

3.2.2   Understand the intelligence tasking process.

- National Technical Means (TENCAP)

- C3 in Crisis

3.3. Understand and identify requirements for C3 systems.

3.3.1   Interface with engineers and operational personnel in the development of new, and the improvement of existing, C3 systems.

- Structured Analysis of System Architecture

- Systems Engineering Process

  •• Mission Needs

  •• Threat Specification

  •• Requirements Analysis

  •• Functional Analysis

  •• Definition of Alternative Architectures

  •• System Analysis & Trade-offs

  •• Concept Selection

  •• Concept Definition

  •• Concept of Operations

  •• Deliverables

- Top-Level Warfare Requirements/TLSR

- Buildability (Physical Realizability)

- Cost and Operational Effectiveness Analysis (COEA)

- National Technical Means (TENCAP)

- System Effectiveness Analysis

- System Utility Functions (Multi-Attribute Decision Theory)

- Functional Analysis & Design

- DoD Standards Setting Process

- Life Cycle Costs

- System & Sub-System Interfaces

- Mission Oriented Approach (MOA)

- Modular C2 Evaluation Structure (MCES)

- Experimentation

  -- Planning Experiments

  -- Designing Experiments

  -- Conducting Experiments

  -- Analysis of Experiments

  -- Reporting Results of Experiments

- User-Developer Relationships

- Engineering Note Book

- •• Current System Parameters

- •• Draft Analysis, Trade-offs, & Other Studies

- •• Library of Resource Material

- •• Team Meeting Minutes

- • C3 in Crisis

- • Future C3 Systems

3.3.2   Interpret the impact of C3 systems on operational philosophies.

- • Structured Analysis of System Architecture

- • Systems Engineering Process

  - •• Mission Needs

  - •• Threat Specification

  - •• Requirements Analysis

  - •• Functional Analysis

  - •• Definition of Alternative Architectures

  - •• System Analysis & Trade-offs

  - •• Concept Selection

  - •• Concept Definition

  - •• Concept of Operations

- •• Deliverables

- • Top-Level Warfare Requirements/TLSR

- • Buildability (Physical Realizability)

- • Cost and Operational Effectiveness Analysis (COEA)

- • National Technical Means (TENCAP)

- • System Effectiveness Analysis

- • System Utility Functions (Multi-Attribute Decision Theory)

- • Functional Analysis & Design

- • DoD Standards Setting Process

- • Life Cycle Costs

- • System & Sub-System Interfaces

- • Mission Oriented Approach (MOA)

- • Modular C2 Evaluation Structure (MCES)

- • Experimentation

  - •• Planning Experiments

  - •• Designing Experiments

  - •• Conducting Experiments

  - •• Analysis of Experiments

  - •• Reporting Results of Experiments

- • User-Developer Relationships

- Engineering Note Book

  •• Current System Parameters

  •• Draft Analysis, Trade-offs, & Other Studies

  •• Library of Resource Material

  •• Team Meeting Minutes

- C3 in Crisis

- Future C3 Systems

- National C3 Policy

3.3.3   Synthesize the command and control needs of the operators/users during

crisis management.

- Structured Analysis of System Architecture

- Systems Engineering Process

  •• Mission Needs

  •• Threat Specification

  •• Requirements Analysis

  •• Functional Analysis

  •• Definition of Alternative Architectures

•• System Analysis & Trade-offs

•• Concept Selection

•• Concept Definition

•• Concept of Operations

•• Deliverables

• Top-Level Warfare Requirements/TLSR

• Buildability (Physical Realizability)

• Cost and Operational Effectiveness Analysis (COEA)

• National Technical Means (TENCAP)

• System Effectiveness Analysis

• System Utility Functions (Multi-Attribute Decision Theory)

• Functional Analysis & Design

• DoD Standards Setting Process

• Life Cycle Costs

• System & Sub-System Interfaces

• Mission Oriented Approach (MOA)

• Modular C2 Evaluation Structure (MCES)

• Experimentation

•• Planning Experiments

•• Designing Experiments

- •• Conducting Experiments

- •• Analysis of Experiments

- •• Reporting Results of Experiments

- • User-Developer Relationships

- • Engineering Note Book

  - •• Current System Parameters

  - •• Draft Analysis, Trade-offs, & Other Studies

  - •• Library of Resource Material

  - •• Team Meeting Minutes

- • C3 in Crisis

3.4 Synthesize the educational and operational experience to determine requirements using systems engineering concepts.

- • Structured Analysis of System Architecture

- • Systems Engineering Process

  - •• Mission Needs

  - •• Threat Specification

  - •• Requirements Analysis

- •• Functional Analysis

- •• Definition of Alternative Architectures

- •• System Analysis & Trades-offs

- •• Concept Selection

- •• Concept Definition

- •• Concept of Operations

- •• Deliverables

- Top-Level Warfare Requirements/TLSR

- Buildability (Physical Realizability)

- Cost and Operational Effectiveness Analysis (COEA)

- National Technical Means (TENCAP)

- System Effectiveness Analysis

- System Utility Functions (Multi-Attribute Decision Theory)

- Functional Analysis & Design

- DoD Standards Setting Process

- Life Cycle Costs

- System & Sub-System Interfaces

- Mission Oriented Approach (MOA)

- Modular C2 Evaluation Structure (MCES)

- Experimentation

- • Planning Experiments

- • Designing Experiments

- • Conducting Experiments

- • Analysis of Experiments

- • Reporting Results of Experiments

- Thesis

- User-Developer Relationships

- Engineering Note Book

  - • Current System Parameters

  - • Draft Analysis, Trade-offs, & Other Studies

  - • Library of Resource Material

  - • Team Meeting Minutes

4. Understand human-C3 systems interactions and related technologies.

4.1. Understand the human's capabilities and limitations and how these can affect the optimum design of C3 systems.

4.1.1   Understand the impacts of different environments (air/land/sea).

- Introduction to Human Factors/Ergonomics

  •• Physical Ergonomics

  •• Mental Ergonomics

  •• Human-Computer Interface

  •• Human-Machine Systems Design

  •• Selection and Design of Displays and Controls

- Introduction to Wide Area Computing

  •• Computer Resource Sharing

    ••• Internet Host to Internet Host

    ••• Personal Computer to Host

  •• Computer Mediated Communication

    ••• one-to-one (e-mail)

    ••• one-to-many (Mailing and discussion Lists)

    ••• Many-to-Many (Bulletin Boards)

  •• Security, Privacy, and Freedom of Speech Issues

4.1.2   Understand the relationships between information processing and collection and information overload (focus on memory).

- Structured Analysis of System Architecture

- National Technical Means (TENCAP)

- Defense Data Network (DDN)

- Human Factors in Systems Design

- Cognitive Science

- Cognitive Illustrations

- Introduction to Human Factors/Ergonomics

  •• Physical Ergonomics

  •• Mental Ergonomics

  •• Human-Computer Interface

  •• Human-Machine Systems Design

  •• Selection and Design of Displays and Controls

- Introduction to Wide Area Computing

  •• Computer Resource Sharing

    ••• Internet Host to Internet Host

    ••• Personal Computer to Host

  •• Computer Mediated Communication

    ••• one-to-one (e-mail)

    ••• one-to-many (Mailing and discussion Lists)

    ••• Many-to-Many (Bulletin Boards)

  •• Security, Privacy, and Freedom of Speech Issues

4.1.3   Understand the applications of technology (e.g., DDN, voice recognition, security devices, data display - graphics, video, etc).

- Introduction to Human Factors/Ergonomics

  •• Physical Ergonomics

  •• Mental Ergonomics

  •• Human-Computer Interface

  •• Human-Machine Systems Design

  •• Selection and Design of Displays and Controls

- Introduction to Wide Area Computing

  •• Computer Resource Sharing

    ••• Internet Host to Internet Host

    ••• Personal Computer to Host

  •• Computer Mediated Communication

    ••• one-to-one (e-mail)

    ••• one-to-many (Mailing and discussion Lists)

    ••• Many-to-Many (Bulletin Boards)

  •• Security, Privacy, and Freedom of Speech Issues

4.1.4. Understand the relationships of accuracy, timeliness, precision, and other factors to the value of information.

- Introduction to Human Factors/Ergonomics

  •• Physical Ergonomics

  •• Mental Ergonomics

  •• Human-Computer Interface

  •• Human-Machine Systems Design

  •• Selection and Design of Displays and Controls

- Introduction to Wide Area Computing

  •• Computer Resource Sharing

    ••• Internet Host to Internet Host

    ••• Personal Computer to Host

  •• Computer Mediated Communication

    ••• one-to-one (e-mail)

    ••• one-to-many (Mailing and discussion Lists)

    ••• Many-to-Many (Bulletin Boards)

  •• Security, Privacy, and Freedom of Speech Issues

- Research Skills

- •• Use of NPS Library

- •• Use of Ergonomics Abstracts

- •• Use of On-line Information Sources

- •• Critical Assessment of the Literature

- Information Engineering 1 & 2

4.2 Understand the application of decision support systems and artificial intelligence to the decision making process.

- Fundamentals of Database Management

  - •• File Processing

  - •• Database Processing (Relational, Hierarchial, Networked)

  - •• Data Definition

  - •• Data Manipulation (Standard Query Language - SQL)

  - •• Data Control (Data Integrated)

  - •• Data Administration

- Artificial Intelligence/Expert Systems Basics

  - •• Knowledge Representation

  - •• Inferencing

•• Neural Networks

• Functions and Characteristics of Decision Support Systems

•• Models of Decision Making

•• Components of A Decision Support System

••• Data Management

••• Model Management

••• User Interface

••• Communications Subsystem

••• Hardware & Physical Facilities

•• System Design (Prototyping)

•• Group Decision Support System

• Cognitive Science

4.3   Understand and apply the concepts of operational analysis as it pertains to the decision making process. Includes areas of probability, model formulation (linear and non-linear programming, networks, flow and scheduling, decision analysis, etc) and statistics and data analysis.

• Probability Concepts

- Understanding Uncertainty

- Probability Models

- Introduction to Statistical Inferences

- Resource Allocation

- Integer Programming

- Linear Programming (LP - e.g. Lindo)

- Risk and Uncertainty

- Multi-Attribute (MA) Decision Analysis

- Game Theory & Solutions using LP

- Flows, Routing and Queuing in Networks 2

- Design of Networks

- Single Variable Differential and Integral Calculus

APPENDIX B

C³ CORE COURSES, TITLES AND MATRIX

C³ Core Courses and Titles

Number	Course Title
CC 3000	Introduction to C3
CC 3001	Modelling C3 Systems
CC 4001	C3 Systems Architecture & Engineering I
CC 4002	C3 Systems Architecture & Engineering II
CC 4003	C3 system Evaluation
CC 4113	C3 Systems Issues
CS 2970	Ada Programming
CS 3030	Computer Organization and Architecture
EO 2710	Introduction to Signals and Systems
EO 2750	Communications Systems

EO 3750	Communications Systems Analysis
IS 4320	Database System & Information Management
MA 1117	Single Variable Calculus
MA 1248	Applied Mathematics
MN 3301	System Acquisition and Project Management
MR 2419	Meteorology for C3
NS 3252	Joint & Maritime Strategic Planning
OS 2103	Applied Probability
OS 3008	Analytical Planning Methodology
OS 3404	Man-Machine Interaction
OS 3603	Simulation and Wargaming
OS 3604	Decision and Data Analysis

C^3 Course Matrix (7 Qtrs)

Fall	NS 3252	MA 1117	CS 2970	CS 3030
Winter	CC 3000	MA 1248	OS 2103	OS 3404
Spring	CC 3001	EO 2710	OS 3604	OS 3008
Summer	CC 4001	EO 2750	MN 3301	IS 4320
Fall	CC 4002	EO 3750	OS 3603	MR 2419
Winter	CC 4003	Elective	Elective	CC 0810
Spring	CC 4113	Elective	CC 0810	CC 0810

APPENDIX C

INTERVIEW DATES AND PROFESSORS

Course	Professor	Date Visited
CC 3000	CDR Allen Tulloch	07 Apr 1992
CC 3001	Capt Wayne Hughs	01 Apr 1992
CC 4001	Prof. Carl Jones	02 Apr 1992
CC 4002	Prof. Carl Jones	02 Apr 1992
CC 4003	Prof. Mike Sovereign	06 Apr 1992
CC 4113	Prof. Mike Sovereign	06 Apr 1992
CS 2970	Capt Pat Barnes	23 Apr 1992
CS 3030	Prof. Lou Stevens	27 Apr 1992
EO 2710	Maj. Tom Schwentner	15 Nov 1991
EO 2750	Maj. Tom Schwentner	15 Nov 1991
EO 3750	Maj. Tom Schwentner	15 Nov 1991
IS 4320	Prof. Dan Dolk	07 Apr 1992

MA 1117	Prof. Carl Jones	26 Nov 1991
MA 1248	Prof. Y. S. Foo	06 Apr 1992
MN 3301	Prof. Marty McCaffrey	02 Apr 1992
MR 2419	Prof. Glendenning	10 Dec 1991
NS 3252	CDR Mitch Brown	09 Apr 1992
OS 2103	Prof. Bill Kemple	07 Apr 1992
OS 3008	Prof. Mike Sovereign	06 apr 1992
OS 3404	Prof. Eric Theise	14 Apr 1992
OS 3603	LCDR Bill Walsh	15 Apr 1992
OS 3604	Prof. Dave Schardy	07 Apr 1992

APPENDIX D COURSES

C3 KNOWLEDGE ELEMENTS LISTED BY CORE COURSES

CC 0810

- Thesis

CC 3000

- Functions of Command

- Process of Command & Control

- Combat operations

- Maneuver Warfare

- U.S. National Command Structure

- NATO C3

- Military Strategy & National Objectives

- Strategic Nuclear Command and Control

- Individual Service Systems

- Tactical Command & Control

- Systems Architecture

- System Evaluation

- Naval Space Master Plan (e.g., Navigation, Communication, Surveillance Systems)

- C^3 Master Plans

- National & Defense Communications Systems (e.g., WWMCCS, DSCS)

- C3 Personnel Issues

- Historical Perspectives of C3

- C3 Process & Organization

  •• OSD/C3I

  •• MCEB

CC 3001

- Combat Theory for C^3

- Nature of Combat Models & Modeling

- MOEs for Warfare (MOEs/MOFEs)

- Analytic Combat Models

  •• Attrition Based Models (Ground and Naval)

  •• Non-Attrition Based Models

- Current Models & Analysis (e.g., JANUS, RESA, CFAW)

- Tactical Influences on C3

- Decision Aids: Construction, Application & Limitations

CC 4001

- Structured Analysis of System Architecture

- Top-Level Warfare Requirements/TLSR

- Buildability (Physical Realizability)

- Cost and Operational Effectiveness Analysis (COEA)

- National Technical Means (TENCAP)

- Flows, Routing and Queuing in Networks 1

- Basic Networking Concepts 1

- Information Engineering 1

- Cognitive Science

- Cognitive Illustrations

- Architecture Examples

  •• FIA

  •• INCA

  •• Copernicus

- DoD/National/International Standards Setting Process

- C^3 Master Plans

CC 4002

- Systems Engineering Process

- • Mission Needs

- • Threat Specification

- • Requirements Analysis

- • Functional Analysis

- • Definition of Alternative Architectures

- • System Analysis & Trade-offs

- • Concept Selection

- • Concept Definition

- • Concept of Operations

- • Deliverables

- Engineering Note Book

  - • Current System Parameters

  - • Draft Analysis, Trade-offs, & Other Studies

  - • Library of Resource Material

  - • Team Meeting Minutes

- System Effectiveness Analysis

- System Utility Functions (Multi-Attribute Decision Theory)

- Functional Analysis & Design

- DoD Standards Setting Process

- Life Cycle Costs

- User-Developer Relationships

- System & Sub-System Interfaces

- Flows, Routing and Queuing in Networks 2

- Basic Networking Concepts 2

- Information Engineering 2

CC 4003

- Mission Oriented Approach (MOA)

- Modular C2 Evaluation Structure (MCES)

- Experimentation

  •• Planning Experiments

  •• Designing Experiments

  •• Conducting Experiments

  •• Analysis of Experiments

  •• Reporting Results of Experiments

- Evaluating & Testing of Simulation and Gaming Software

CC 4113

- C3 in Crisis

- Future C3 Systems

- Joint Headquarters C3 Systems

- Combined C3 Systems

- National C3 Policy

CS 2970

- Program Design

- Standard Types

- Identifiers

- Literals

- Assignment Statements

- Expressions

- Conditionals & Iterations

- Sub-programs

  •• Functions

  •• Procedures

- Packages

- Input & Output

CS 3030

- Basic Computer Architecture

- Data Representation

- Principles of Digital Logic Circuits

- Elements of Microprogramming

- Principles of Assembly Language

- Operating System Concepts

  •• Process Management

  •• File Management

  •• Memory Management

EO 2710

- Communication Systems Schematic.

- Transfer Functions

- Amplitude Response

- Phase Response.

- Ideal Filter Response.

- Non-Ideal Filter Approximations.

- Signal Description and Detection.

- Time and Frequency Domain Representations of Random Signals.

EO 2750

- Sampling Theorem.

- Modulation (PAM, PCM, TDM, FDM, QPSK).

- Noise Types and Modelling

    •• Thermal, Power Spectrum, Equivalent Noise Bandwidth, Bandpass, Noise Modulation Products.

- AM & FM System Performance in Noise.

EO 3750

- Comparative Performance of Analog and Digital Modulation Types in the Presence of Noise.

- Signal to Noise Ratio and Bit Error Rate and E_b/N_o.

- Antenna Fundamentals and Characteristics.

- Radar Equations.

- Path Calculations and Link Budget.

- Microwave (Terrestrial and Satellite) Link Equations.

- Ionospheric & Tropospheric & Meteorologic Effects on Propagation.

IS 4320

- Fundamentals of Database Management

  •• File Processing

  •• Database Processing (Relational, Hierarchial, Networked)

  •• Data Definition

  •• Data Manipulation (Standard Query Language - SQL)

  •• Data Control (Data Integrated)

  •• Data Administration

- Artificial Intelligence/Expert Systems Basics

  •• Knowledge Representation

  •• Inferencing

  •• Neural Networks

- Functions and Characteristics of Decision Support Systems

  •• Models of Decision Making

  •• Components of A Decision Support System

    ••• Data Management

    ••• Model Management

    ••• User Interface

    ••• Communications Subsystem

    ••• Hardware & Physical Facilities

  •• System Design (Prototyping)

•• Group Decision Support System

MA 1117

- Single Variable Differential and Integral Calculus.

- Real and Complex Numbers.

MA 1248

- Sequences and Series

- Fourier Series

- Periodic and Special Wave Form Analysis

- Fourier Transforms

- Time and Frequency Domain Representation of Wave Forms

- Convolution and Correlation

MN 3301

- History of Acquisition

- The Acquisition Process (e.g., CINC PPBS)

- DAB/Program Baseline

- PPBS/Cost Estimates

- Acquisition Strategies (e.g., COTS, NDI, PPPI, Milspec, Evol.)

- Acquisition Plan

- Contracting Process & Administration

- Test & Evaluation

- Integrated Logistics Support (ILS)

MR 2419

- HF propagation

- UHF Propagation

- VHF Propagation

- Microwave(Radar) Propagation

NS 3252

- Historical Evolution of Strategy, Maritime Strategy, and U.S. Defense Policy

- Principles of War

- Chain of Command

- Joint Planning Doctrine & Organization

- Service Unique Doctrine

- •• Navy

- •• Army

- •• Air Force

- •• Marine Corps

- •• Coast Guard

- • Alliance and Regional Policy Issues

- • Nuclear Issues

- • Arms Control

- • Other Navies

- • Military Force and Foreign Policy

- • Current Issues in Defense Reform/Reorganization

OS 2103

- • Probability Concepts

- • Understanding Uncertainty

- • Probability Models

- • Introduction to Statistical Inferences

OS 3604

- Data Analysis

- Point & Interval Estimation

- Test of Hypothesis

- Statistical Inferences

- Non-Parametric Tests

- Design of Experiments (ANOVA)

- Linear Regression

- Analysis of Categorical Data

- Applications

OS 3008

- Resource Allocation and Constrained Optimization

- Integer Programming

- Linear Programming (LP - e.g., Lindo)

  - Mathematical/Problem Formulation

  - Simplex Method

  - Graphical Solutions Methods

  - Assignment Problems

  - Multi-Period Planning

- •• Inventory & Product Mix Planning

- •• Munitions Planning

- • Risk and Uncertainty

- • Multi-Attribute (MA) Decision Analysis

- • Game Theory & Solutions using LP

- • Flows, Routing and Queuing in Networks 1

- • Design of Networks

- • Modeling Networks

- • MOE

OS 3404

- • Introduction to Human Factors/Ergonomics

  - •• Physical Ergonomics

  - •• Mental Ergonomics

  - •• Human-Computer Interface

  - •• Human-Machine Systems Design

  - •• Selection and Design of Displays and Controls

- • Introduction to Wide Area Computing

  - •• Computer Resource Sharing

    - ••• Internet Host to Internet Host

- ••• Personal Computer to Host

- •• Computer Mediated Communication

  - ••• one-to-one (e-mail)

  - ••• one-to-many (Mailing and discussion Lists)

  - ••• Many-to-Many (Bulletin Boards)

- •• Security, Privacy, and Freedom of Speech Issues

- • Research Skills

  - •• Use of NPS Library

  - •• Use of Ergonomics Abstracts

  - •• Use of On-line Information Sources

  - •• Critical Assessment of the Literature

OS 3603

- • Modeling Process

- • Simulation language Types (Generic, Specific)

- • Simulation Methodology

- • Simulation Algorithms

- • Discrete Event Simulation

- • Random Number Generation

- • Input Data Analysis

- Verification & Validation

- Sample Size and Replication

- War Gaming

  •• Types of War Games (e.g., Seminar, Computer Assisted)

  •• Specific War Games (e.g., JANUS, RESA)

APPENDIX E

ESRs MAPPED TO COURSES

1.1.1	EO 2710, EO 2750, EO 3750, MA 1117, MA 1248
1.1.2	CC 4001, CC 4002, EO 3750, MA 1117, MA 1248, MR 2419, OS 3008
1.2	CS 2970, CS 3030, OS 3404
1.3	IS 4320
1.4.1	CC 4113, MN 3301, OS 3604
2.1	CC 4001, CC 4002, CC 4003, OS 3604
2.2.1	CC 3001, CC 4003, OS 3603, OS 3604
2.2.2	CC 3000, CC 4113, NS 3252
2.3	CC 3000, CC 4002
3.1.1	CC 3000, CC 4113
3.1.2	CC 3000, CC 4113
3.1.3	CC 3000, NS 3252
3.2.1	CC 4001, CC 4113
3.2.2	CC 4001, CC 4113

3.3.1 CC 4001, CC 4002, CC 4003, CC 4113

3.3.2 CC 4001, CC 4002, CC 4003, CC 4113

3.3.3 CC 4001, CC 4002, CC 4003, CC 4113

3.4 CC 0810, CC 4001, CC 4002, CC 4003

4.1.1 OS 3404

4.1.2 OS 3404

4.1.3 OS 3404

4.1.4 CC 4001, CC 4002, OS 3404

4.2 CC 4001, IS 4320

4.3 MA 1117, OS 2103, OS 3008

APPENDIX F

COURSES MAPPED TO ESRs

CC 3000   2.2.2, 2.3, 3.1.1, 3.1.2, 3.1.3

CC 3001   2.2.1

CC 4001   1.2, 2.1, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.4,4.1.4, 4.2

CC 4002   1.2, 2.1, 2.3, 3.3.1, 3.3.2, 3.3.3, 3.4, 4.1.4

CC 4003   2.1, 2.2.1, 3.3.1, 3.4

CC 4113   1.4.1, 2.2.2, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2,

               3.3.3

CS 2970   1.2

CS 3030   1.2

EO 2710   1.1.1

EO 2750   1.1.1

EO 3750   1.1.1, 1.1.2

IS 4320   1.3, 4.2

MA 1117   1.1.1, 1.1.2, 4.3

MA 1248   1.1.1, 1.1.2

MN 3301   1.4.1

MR 2419   1.1.2

NS 3252   2.2.2, 3.1.3

OS 2103   4.3

OS 3008   1.2, 4.3

OS 3404   1.2, 4.1.1, 4.1.2, 4.1.3, 4.1.4

OS 3603   2.2.1

OS 3604   1.4.1, 2.1, 2.2.1

APPENDIX G

HYPERTEXT AND MULTIMEDIA

TABLE OF CONTENTS

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HYPERTEXT AND MULTIMEDIA

Hypertext and multimedia are new software and hardware methods of organizing and displaying data on computers. The data can be stored on the computer itself or on auxiliary storage devices. The remainder of this appendix will help a user to become acquainted with hypertext and multimedia and the possibilities that they offer.

A. HYPERTEXT

Hypertext is not the name of a software product. It is the name of a technology. It can be found in use on many different computer systems today. There are also several different vendors that produce software that use hypertext technology. Today, hypertext is being used within several software programs. Many times the user is not even aware that they are working with hypertext technology. All they know is that they are able to get the information that they desired without a lot of trouble.

1. What is Hypertext

Hypertext is a method of storing information on a computer in a non-linear method. This approach is different that the linear method of storing information. For example, when someone reads a book they must start at the

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beginning of the text and go page-by-page until they reach the end. If there is a word or phrase that they do not understand then they must stop where they are and locate the part of the book that defines that word or phrase they are looking for. Don't forget that they must mark the page where they were at. When they have found the information that they want they can then go back to where they were reading, assuming that they did not lose their place, and continue. The reader must follow these steps for every word or phrase they don't understand. This can be very time consuming. Often it becomes so much of a task that readers skip over information they don't understand.

Now, with a hypertext system they can be reading a book, on a computer, and come to a word or phrase that they don't understand. This time, however, they don't have to mark their place and go off looking for the location of the information they desire. They can simply press a button on their mouse and the word's or phrase's definition is displayed in a small window on their computer screen. When the reader lets up on the button the definition disappears.

This use of hypertext is not limited to displaying definitions. It can also take readers directly to the location of the word or phase they have a question about. Hypertext could also go to another file and display more information for them.

Another feature of hypertext systems is the ability to backtrack to where the user just came from. Buttons of this type are referred to as navigation buttons. They provide the user several different navigation tools, such as:

- Go to end of file

- Go to top of file

- Go to next frame (a logical division of a computer file)

- Go to previous frame

- Exit

- Help

These tools are provided so that the user can easily move around the document or files that they are examining.

2.   How Hypertext is Used Today

Any user who has ever used the "Help" function when in MicroSoft Windows has used Hypertext. MicroSoft Windows' help function is just one of several help functions that are in use today. Other companies such a Word Perfect for Windows, MicroSoft Excel for Windows, Mathcad for Windows and Power Point for Windows all have help functions that use hypertext.

The use of hypertext is not limited to Windows applications. The Defense Language Institute (DLI) located in Monterey, California, uses hypertext to help teach the Russian language to its students.[Ref 1] Other uses for hypertext could include auto repair manuals, technical drawings and multimedia applications.

B. MULTIMEDIA

When people hear the word multimedia they should think of many types of media. This is a technology that is combining the personal computer, VCRs, CD ROM disk drives and television. This includes the use of sound along with the visual display. Multimedia is opening many new areas and is enhancing many old ones. It is safe to say that multimedia is here to stay.

1. What is Multimedia

Multimedia is the use of multiple types of media, and any necessary software, with a computer. Multimedia types include, but are not limited to, television, video from a VCR, graphics from a digitized file, graphics from a disk drive and sound from a variety of sources.

Multimedia is not hypertext. Multimedia can run on a system by itself. Hypertext is not needed to have a multimedia computer system although multimedia can be part of a hypertext system.

2. How is Multimedia Used

Multimedia and its use are in their infancy. Many software products are just now emerging with multimedia capability. Computer software, including computer games, are now being sold with multimedia capabilities. The newest version of MicroSoft Windows has multimedia "hooks" in it. Several computer games are already being sold that use multimedia.

a. Current Uses

Educational institutions are among the most visible users of multimedia today. Stanford University uses a multimedia system to teach its students surgery.[Ref 2] Another application is a trip through a town. All possible streets have been filmed and stored on a disk drive. The user can then navigate around town turning up and down any street that they choose. All the while they are seeing pictures of the street along with the sounds, just as if they were actually driving down the street.[Ref 2]

b. Future Uses

Imagine someone sitting down at a computer and getting information about the history of the U. S. Air Force. They could see historical pictures that are accompanied by a narration of what they are viewing. The users could see a video-taped computer demonstration of a course they are taking while using the software that was needed for that course. Users could send and receive electronic,

voice, and video mail. They could be reading this thesis and executing the software that is discussed in Chapter V at the same time. Future uses of multimedia are almost limitless.

3.   Combining Multimedia and Hypertext

Getting computer data along with audio and visual images is enhanced by the use of hypertext. The DLI system talked about earlier in this appendix combines hypertext and multimedia.[Ref 1] It uses hypertext to link the information together. It also uses multimedia to enhance the information that DLI wants their students to learn. This includes the use of pictures, video and sound. The system displays pictures of different locations in Russia while at the same time it is showing the student different words to say and then pronouncing the words. Hypertext and multimedia used together are limited only by one's imagination.

Someone could be giving a briefing to senior officer. They could be producing an expanded help function for a new software product that not only shows the user what to do but includes some verbal instruction as well. These and many other applications will soon be commonplace, and we'll wonder how we ever got along without these technologies.

LIST OF REFERENCES

1. *The Computer Chronicles*, Program 920 - Foreign Language Software, Television Station WITF, Harrisburg, Pennsylvania.

2. *The Computer Chronicles*, Program 814 - Hypertext, Television Station WITF, Harrisburg, Pennsylvania.

3. Schrage, L., *Linear, Integer and Quadratic Programming with LINDO*, 3rd Edition, p. 124, The Scientific Press, 1986.

4. OWL International, *Guide Users Manual*, p. 2-1, 1990.

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